EFFECTS OF EXPOSURE TO ELEVATED TEMPERATURES ON THE BOND CHARACTERISTICS BETWEEN NORMAL CONCRETE SUBSTRATE AND ULTRA HIGH PERFORMANCE FIBER REINFORCED CEMENTITIOUS COMPOSITES

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by

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D	Number of scale divisions
f	Flow
t	Test point time period
T	The splitting tensile strength
P	Maximum applied load
L	Length of specimen

LIST OF ABBREVIATIONS

AC	As cast
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BS EN	British European Standards Specifications
$Ca(OH)_2$ or CH	Calcium hydroxide
CaO	Calcium Oxide
$CaCO_3$	Calcium carbonate
CO_2	Carbon dioxide
CARDIFRC	CARDIF-reinforced concrete
COV (%)	Coefficient of variance
C-S-H	Calcium silicate hydrates
C_3A	Tricalcium aluminate
DR	Drilled holes
DSF	Densified silica fume
FA	Fly ash
GBFS	Ground blast furnace slag
GPOFA	Ground-POFA
GUSMRC	Green Universiti Sains Malaysia Reinforced Concrete
GR	Grooved
HPC	High performance concrete

HSC	High strength concrete
HSGC	High strength green concrete
HRWR	High range water reducer
H_2O	Water
ISAT	Initial surface absorption test
MOE	Modulus of elasticity
NC	Normal concrete
OPC	Ordinary Portland Cement
RC	Reinforced concrete
POFA	Palm oil fuel ash
UPV	Ultrasonic pulse velocity
SB	Sand blasted
SEM	Scanning electron microscope
SF	Silica fume
S.D	Standard deviation value
SP	Superplasticizer
SiO_2	Silicon dioxide
TPOFA	Treated-POFA
UHPFC	Ultra high performance fiber reinforced concrete
UHPFRCC	Ultra-high performance fiber reinforced cementitious composites
UPOFA	Ultrafine-POFA

WB	Wire brushed
W/B	Water/binder ratio
W/C	Water/cement ratio

KESAN PENDEDAHAN KEPADA SUHU YANG TINGGI TERHADAP CIRI-CIRI IKATAN ANTARA KONKRIT BIASA DAN KOMPOSIT BERSIMEN BERTETULANG GENTIAN BERPRESTASI ULTRA TINGGI

ABSTRAK

UHPFRCC kebiasaannya digunakan dalam pembinaan jambatan, pembaikan empangan, bangunan dan struktur konkrit yang lain. Kekuatan ikatan yang bagus antara konkrit lama dengan lapisan bahan pembaikan yang baru merupakan salah satu faktor dalam meningkatkan prestasi pembaikan konkrit. Walaubagaimanapun, konkrit akan terjejas apabila didedahkan kepada suhu yang tinggi dan jaminan kualiti kekuatan ikatan memerlukan kaedah yang boleh menilai kekuatan serta mengenal pasti jenis kegagalan. UHPFRCC hijau baru yang mana telah dipatenkan sebagai Universiti Sains Malaysia konkrit hijau bertetulang (GUSMRC) telah dicipta. Konkrit ini mengandungi 50 peratus jumlah simen dengan bahan pozolanik, iaitu POFA ultra halus (UPOFA). Objektif kajian ini iaitu untuk menyiasat ikatan antara muka apabila dikenakan pada suhu antara 100ºC, 200ºC, 300ºC, 400ºC and 500ºC terhadap konkrit lama dan bahan baikpulih baru. GUSMRC telah digunakan sebagai bahan baik pulih baru dimana dua jenis kekasaran permukaan digunakan iaitu letupan pasir (sand blast) dan berlurah (grinding). Perubahan sifat-sifat kejuruteraan keatas sampel tunggal bahan baikpulih serta konkrit biasa juga dikaji selepas didedahkan pada suhu ternaik. Untuk pengujian sifat-sifat mekanikal dalam ikatan, ia diuji dengan menggunakan kaedah lereng ricih (slant shear), ujian ketegangan (splitting tensile), pull-off test dan ujian lenturan (flexural strength) untuk menentukan pengaruh kekasaran permukaan dan menguji kesan terhadap konkrit apabila dikenakan pada suhu yang tinggi. Keputusan menunjukkan lapisan konkrit

hijau mencapai ikatan antara muka yang tinggi dan sesuai disamping konkrit biasa. Tekstur lapisan letupan pasir menunjukkan ikatan antara muka yang tinggi jika dibandingkan dengan jenis berlurah sebelum dan selepas dikenakan suhu yang tinggi. Kebanyakan mod kegagalan berlaku pada konkrit biasa dan secara automatik membuktikan ikatan antara dua muka adalah kuat. Kehilangan kekuatan konkrit yang kritikal untuk GUSMRC dicatatkan pada suhu 400^{o}C and 500^{o}C.

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ABSTRACT

UHPFRCC is usually applied to rehabilitation bridge of dam, building and other structures. Good bond strength between old concrete substrate and a newly overlaid repair material is a very important factor in assuring the performance of concrete repairs. However, the properties of concrete would be affected when it is exposed to high temperature. The quality assurance of the bond strength requires methods that can quantify the bond strength as well as identify the failure mode. A newly patented class of green UHPFRCC known as green Universiti Sains Malaysia reinforced concrete (GUSMRC) was developed. This concrete contains 50% of the cement total volume by pozzolanic material, ultra-fine POFA (UPOFA). The objective of this study is to evaluate the interfacial bonding characteristics between old concrete and new repair material after the composite is exposed to elevated temperatures of 100^{o}C, 200^{o}C, 300^{o}C, 400^{o}C and 500^{o}C. GUSMRC was applied as the new repair material on the normal concrete substrate and the surface has been prepared / roughened either by sand blasting (SB) or grinding (GR). In addition, changes on the mechanical properties of the monolithic samples of the repair material as well as the normal concrete substrate were also evaluated after the exposure to the elevated temperatures. The characteristic of interfacial bond were assessed using the slant shear, pull-off, splitting tensile, and flexural strength test to evaluate the influence of two types of surface roughness and to evaluate the effect after the exposure to

elevated temperatures. The results showed that the new green concrete overlay achieved good bond strength with the NC. Sand blasting surface treatment showed the excellent bonding properties compared to grinding before and after the exposure to the elevated temperatures. Mostly all the failure modes showed failures at NC substrate and automatically proved that the bondings between two layers are strong. The critical loss of strength for GUSMRC was recorded at 400^{o}C and 500^{o}C.

CHAPTER ONE

INTRODUCTION

1.1 Background

Ultra-high performance fiber reinforced concrete (UHPFRC) is a type of concrete which has a compressive strength reaching 150MPa by improving the mix proportion of raw materials. This type of concrete has a record with high value in strength, durability and advanced performance according to Fardis (2012). Plus, UHPFRC is a super plasticized concrete with fibres as an improvement to achieve homogeneous mixes by the replacement of coarse aggregate with fine sand as stated by Richard *et al.* (1995). UHPFRC is well known due to its qualities in comparison with normal concrete (NC) and high performance concrete (HPC). The proportion of cement, silica fume, steel fiber and chemical admixtures made it has potential to develop a dense structure of concrete according to Hertz (2003). This ultra-fine particle fill out the void space and it greatly becomes dense and the different physical and chemical changes occurred between normal concrete and a concrete with a dense microstructure. The compressive strength of the dense concrete increases due to the high cement content, however, the overproduction of cement will increase the greenhouse gas emission and cause global warming (Worrel *et al.*, 2001; Arshad *et al.*, 2010). By replacing a greater amount of the cement and silica fume in UHPFRC mixes while maintaining its mechanical properties could be the best key. The partial replacement of ordinary Portland cement (OPC) by manufacturing wastes as supplementary cementitious materials such as palm oil fuel ash (POFA) could enhance the transport properties of concrete (Tay *et al.*, 1990; Tangchirapat *et al.*,